Energy in the future

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DLR
German Aerospace Center

- Research Institution
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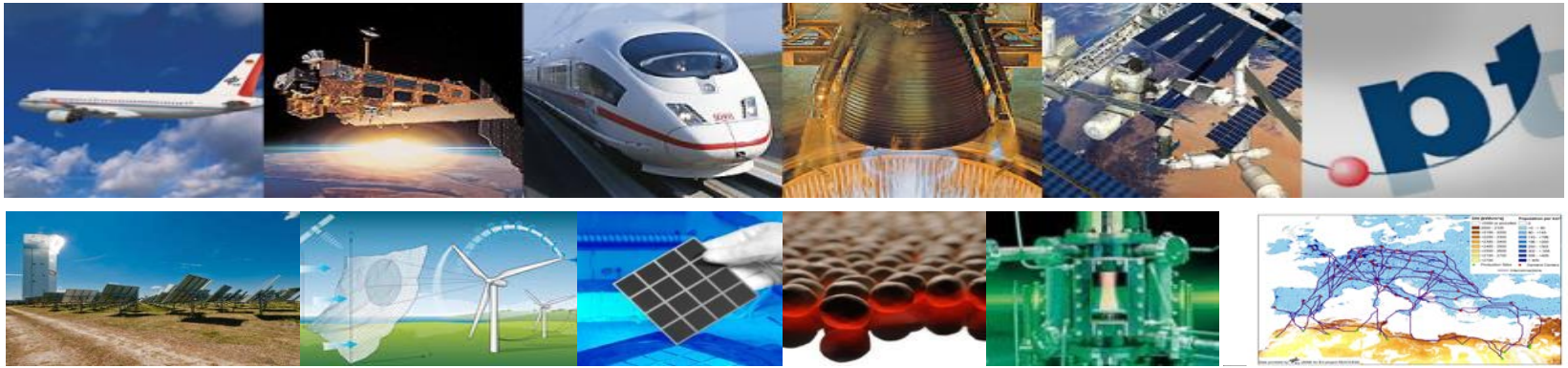
Energy

- **Solar**
- **Wind**
- **Thermal & Chemical Storage**
- **Fuel Cells**
- **Gas Turbines**
- **System Analyses**



Content

- Agglomeration of the world population
- Growth of MegaCities
- Decentralized regenerative supply of MegaCities
- Regenerative resource versus location of MegaCities
- Centralized supply (Regenerative Hotspots) of MegaCities: example Beijing
- 100% security of supply by „Regenerative Hotspots“

Interesting facts

- In 1800, only 3% of the world's population lived in cities
- By the end of the 20th century, 47% lived in cities
- In 1950, there were 83 cities with populations exceeding one million
- In 2007, this number had risen to 468
- If the trend continues, the world's urban population will double every 38 years
- The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities.

- http://en.wikipedia.org/wiki/Megacity

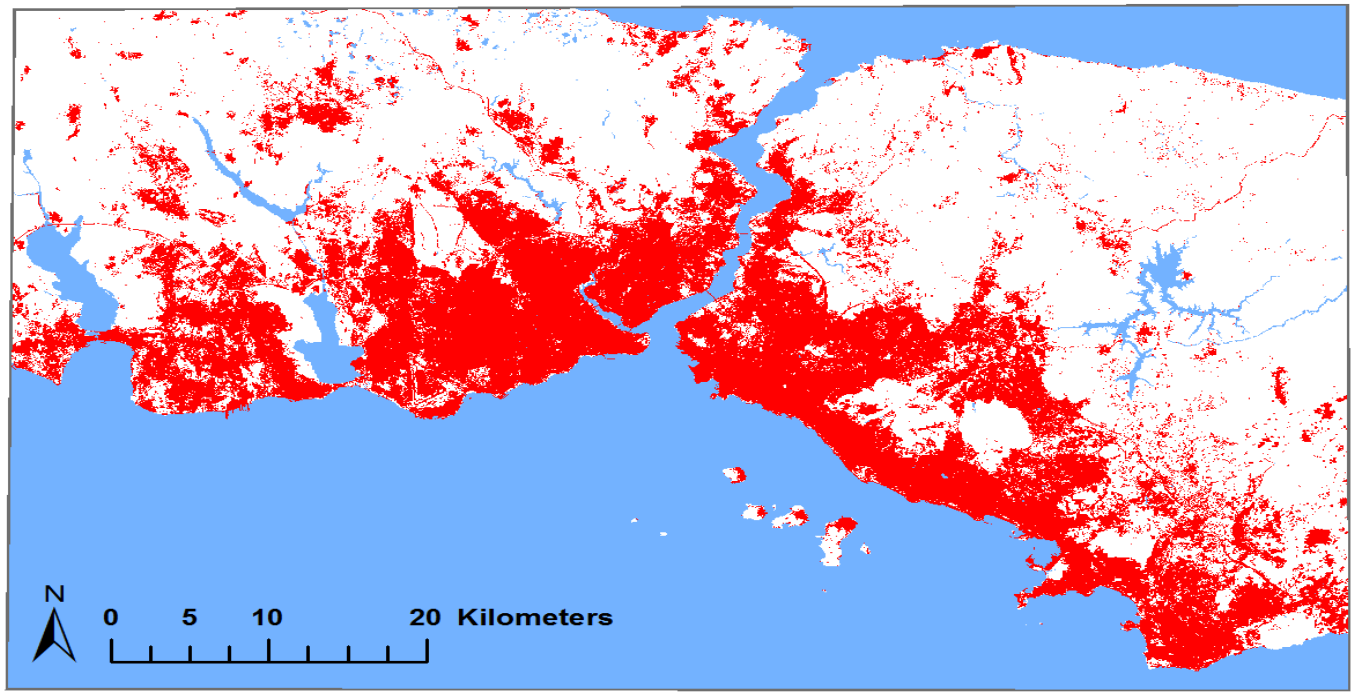
Urban Growing

Istanbul 1975

Istanbul 1990

Istanbul 2000

Istanbul 2010



Taubenböck H, Esch T, Felbier A, Wiesner M, Roth A, Dech S (2012): *Monitoring of mega cities from space.* Remote Sensing of Environment, vol. 117, pp. 162-176.

Urban Growing

Shanghai 1975

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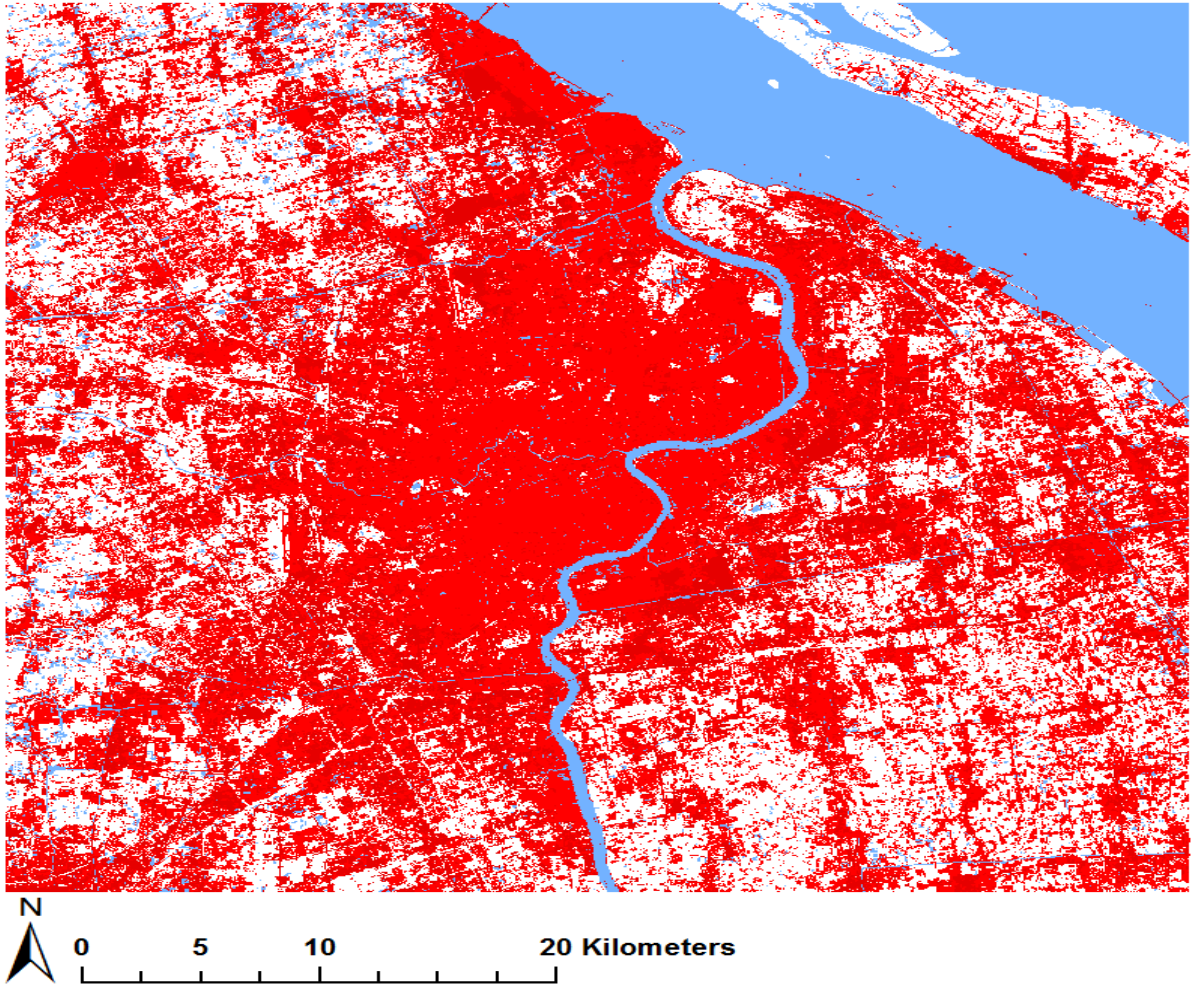

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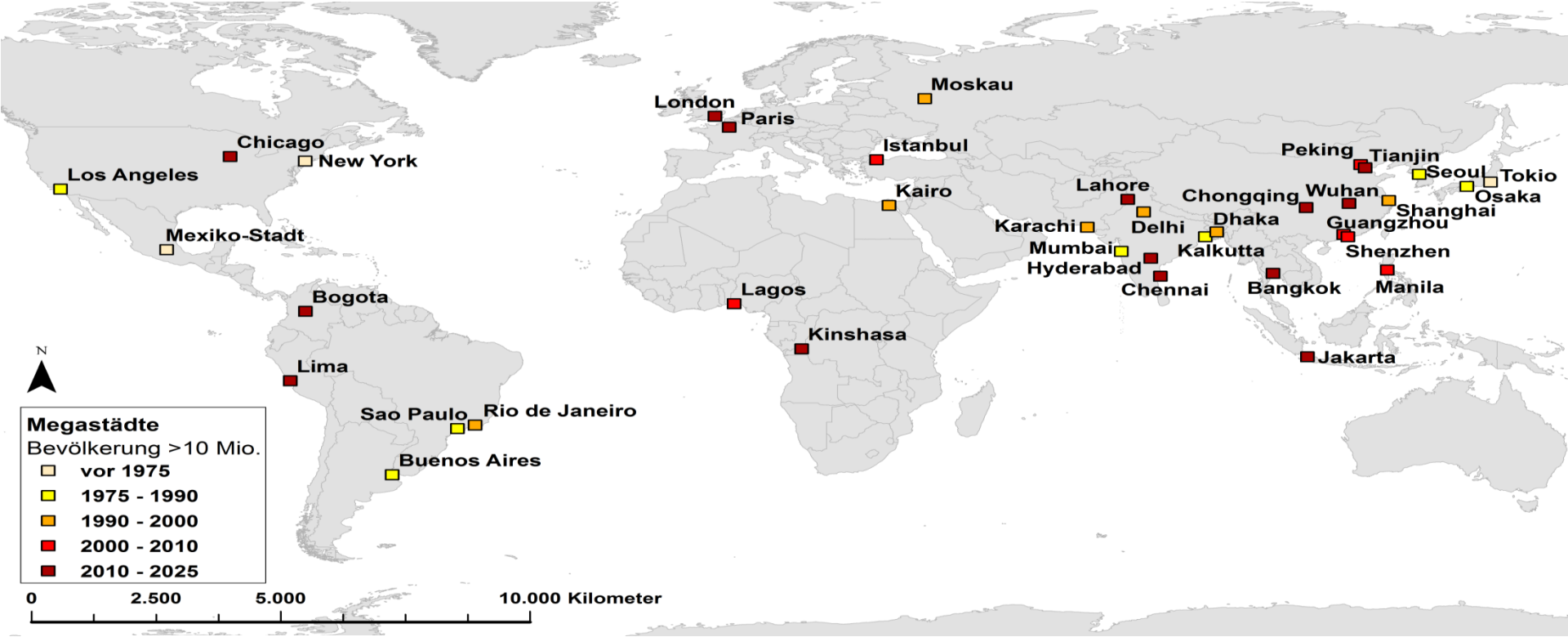
MegaCities



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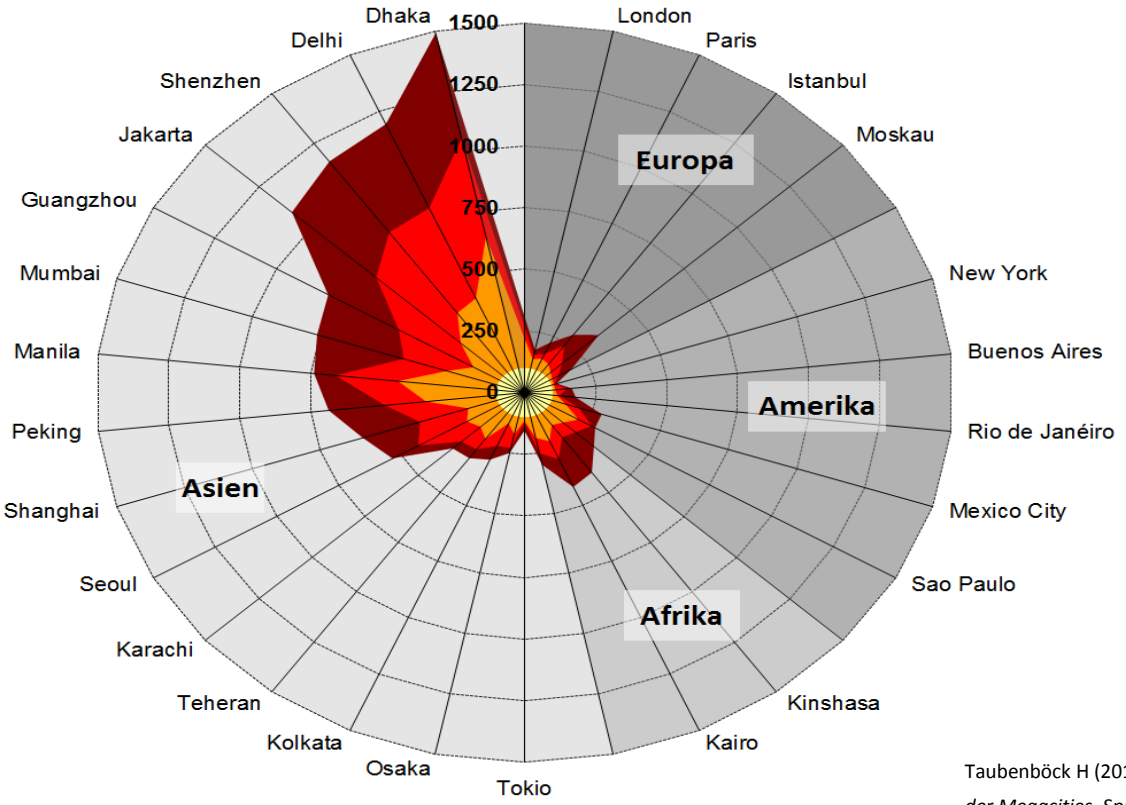
Relative Grow-rate in size of MegaCities



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MegaCities

Europe – Afrika - Amerika

- **Moscow** **17**
- **London** **14**
- **Paris** **12**
- **Rhine-Ruhr** **11**
- **Istanbul** **15**

- **Lagos** **21**
- **Cairo** **19**
- **Kinshasa** **13**

- **New York City** **24**
- **Mexico City** **22**
- **Los Angeles** **19**
- **São Paulo** **21**
- **Buenos Aires** **17**
- **Rio de Janeiro** **14**

• Asia

- Tokyo-Yokohama 38
- Jakarta 30
- Seoul 26
- Delhi 26
- Shanghai 25
- Karachi 24
- Beijing 22
- Mumbai 21
- Osaka 20
- Manila 20
- Dhaka 18
- Bangkok 15
- Kolkata 15
- Tehran 13
- Guangzhou 13
- Shenzhen 12

Attributes of MegaCities

- Positive - Opportunities

1. **higher probability of social rise up**
2. arts and culture atmosphere/events/
3. opportunities
4. educational opportunities
5. higher qualified jobs
6. higher paying jobs/economic opportunities
7. ..
8. .

- Negative - Challenges

1. trash pollution
2. slums
3. traffic congestion
4. water pollution
5. lack of basic needs – electricity/water
6. civil unrest
7. housing shortages/homelessness
8. transportation
9. political fighting
10. lack of basic sanitation
11. pollution of beaches and natural resources
12. inadequate infrastructure (roads)
13. public transportation
14. air pollution
15. lack of recreation areas
16. health risks/diseases

Tokyo, Japan

Current population = 36.7 million
Estimated population 2025 = 37.1 million

Delhi, India

Current population = 22.2 million
Estimated population 2025 = 28.6 million

Mexico City, Mexico

Current population = 19.5 million
Estimated population 2025 = 20.7 million

New York City

Current population = 20.4 million
Estimated population 2025 = 20.6 million

Sao Paulo, Brazil

Current population = 19.9 million
Estimated population 2025 = 23.7 million

Dhaka, Bangladesh

Current population = 14.6 million
Estimated population 2025 = 20.9 million

Calcutta, India

Current population = 15.6 million
Estimated population 2025 = 20.1 million

2050 around 75% of the world population lives on less than 2,8% of the world surface!

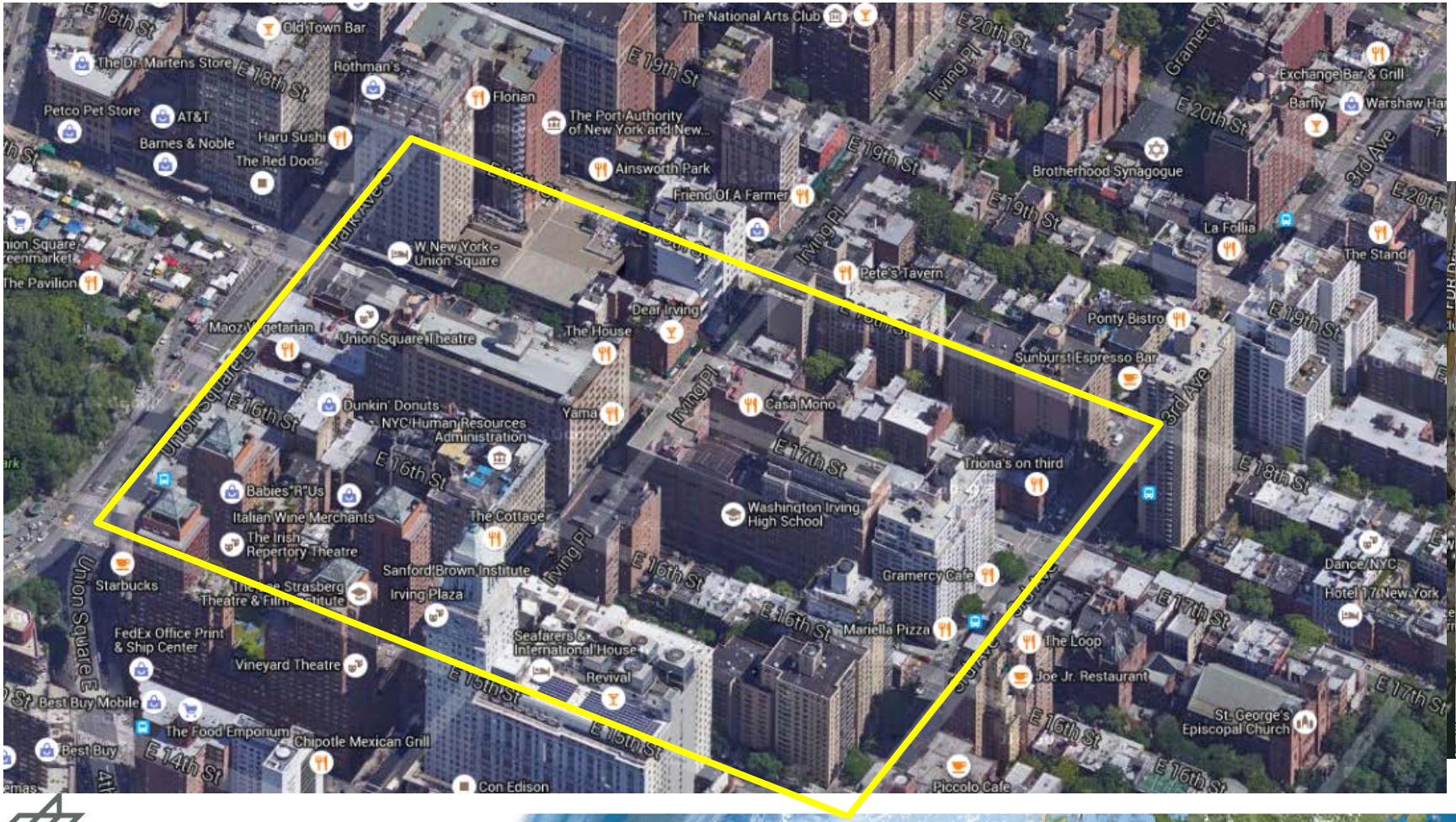
But: Could MegaCities supply their own electricity?

Taubenböck H (2015): *Ohne Limit? Das Flächenwachstum der Megacities.*

Could MegaCities supply their own electricity?

- wind energy — not possible
- solar thermal power plant CSP — not possible
- PV — possible but limited

Source : Google Earth



Source : Google Earth

New York City, Manhattan

usable city area

- max. 30%

- Realistic according to a study by the TU Berlin for the Greater Berlin ca. 10-20% (Source: www.pvupscale.org)

Source : Google Earth

Example Beijing

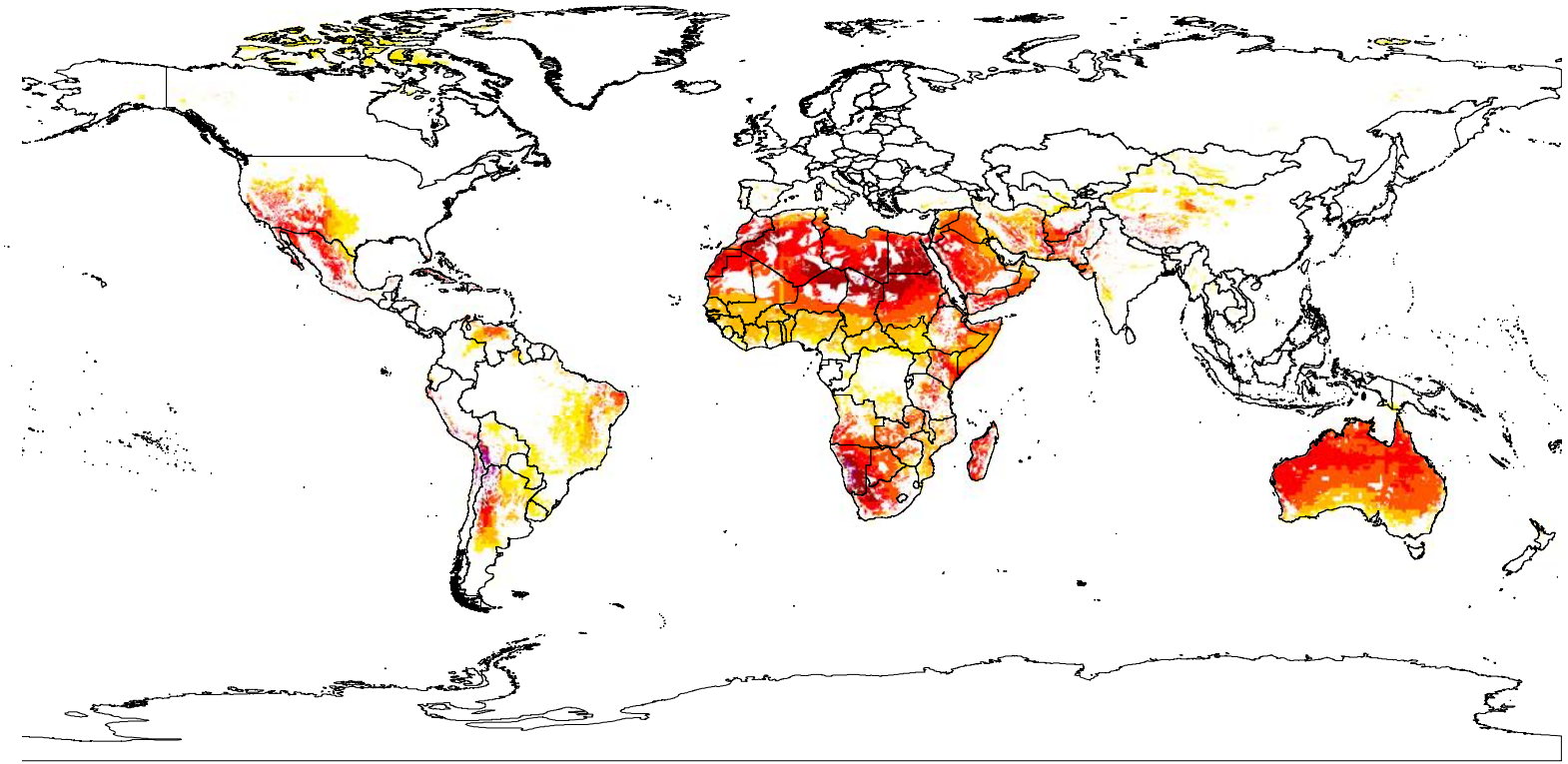
- Future MegaCity Beijing with 130 million inhabitants

- Today's electricity demand >100TWh/a
- Today's area of the city
  - App. 470 km^2
  - 25000 people/km^2 (value: Manhattan)
  - and 11,8 Mio inhabitants
- Maximum own production by 20% usage of city area for PV: 14,2 TWh/a

In highly condensed metropolitan areas only a maximum of 15% of the electricity requirement can be generated itself? But still fluctuating

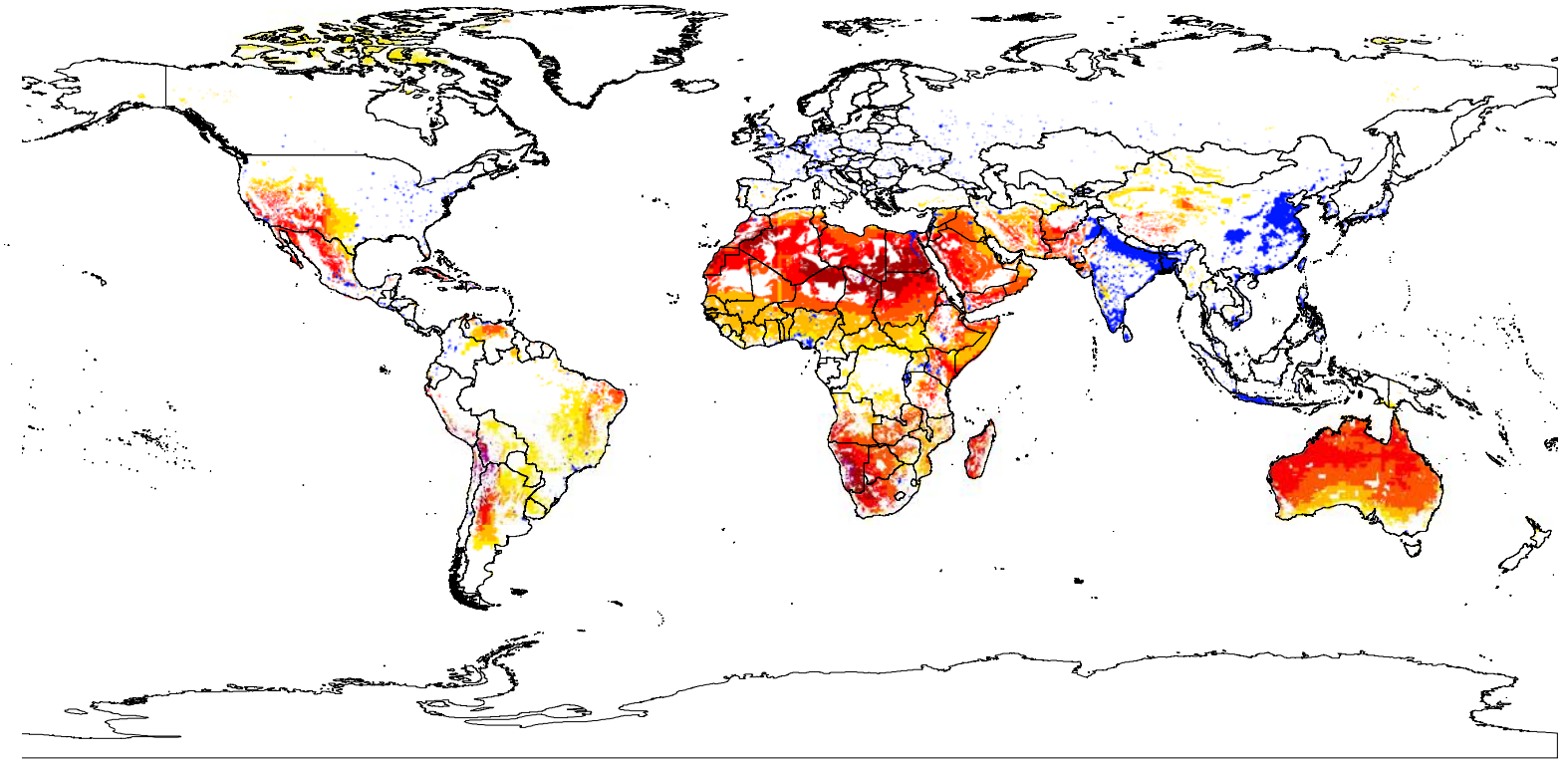
Source: DPA, Beijing at night

Solar Potential



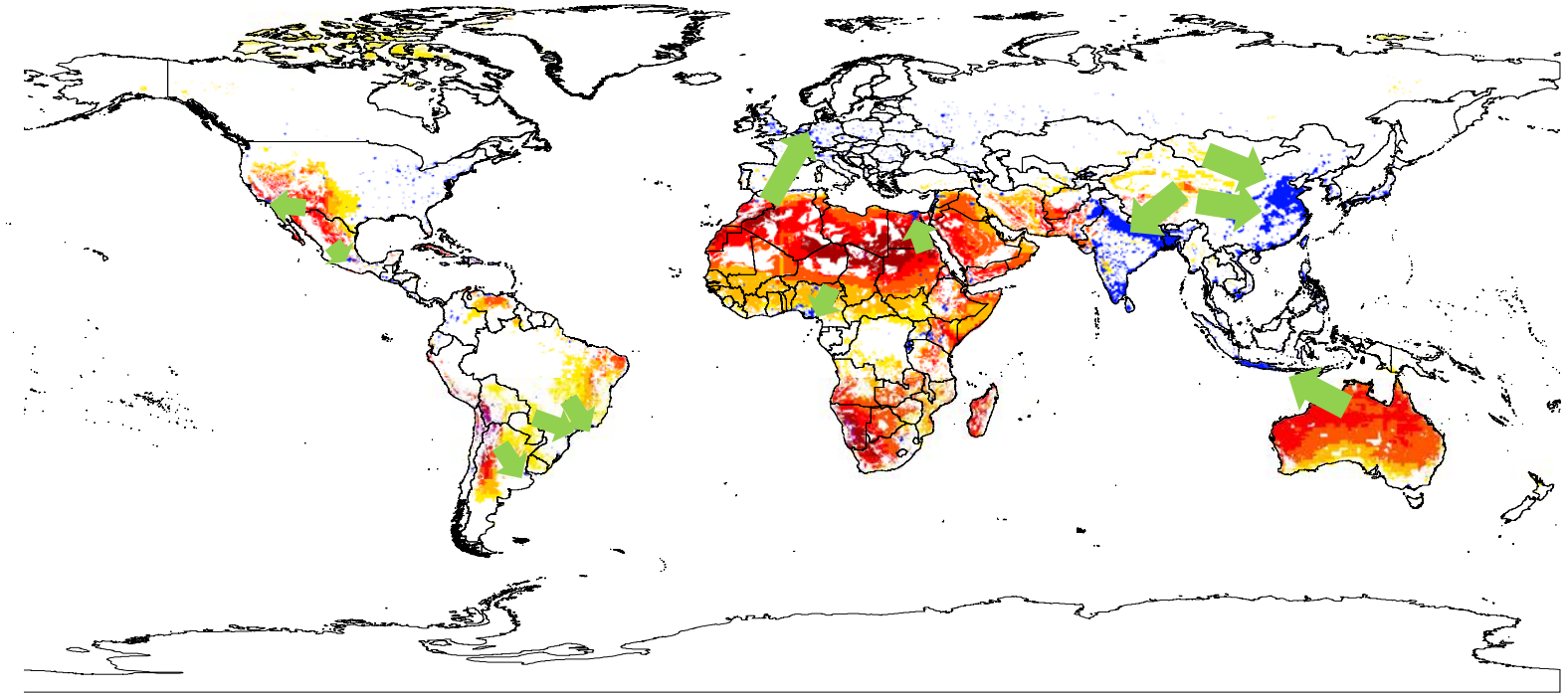
Source: DLR

Regenerative resource versus location of MegaCities



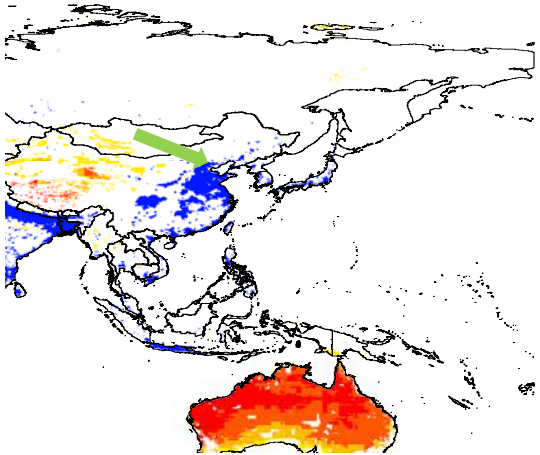
Quelle: DLR

Solare Hotspots versus MegaCities



Quelle: DLR

Solar Hotspot of Beijing

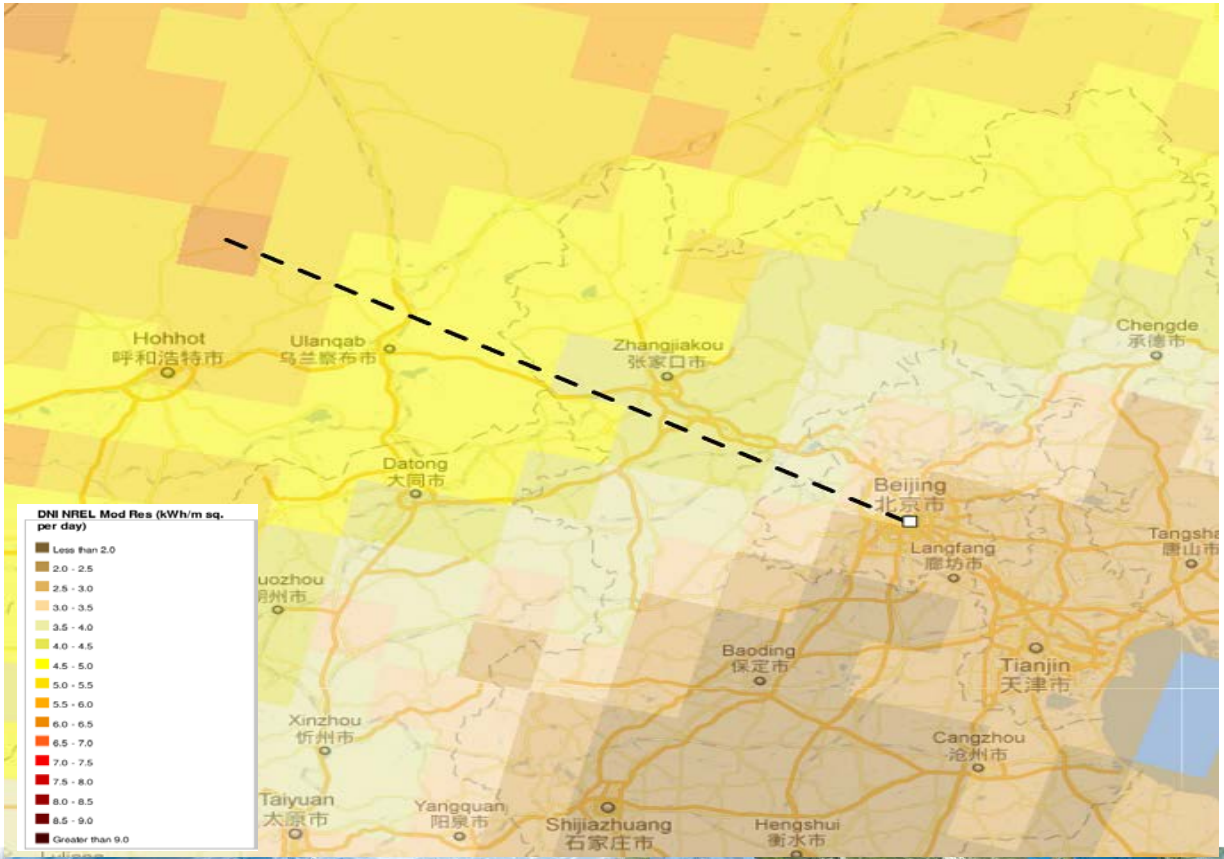


Source: DLR

Solar Hotspot for Beijing

Solar Hotspot:

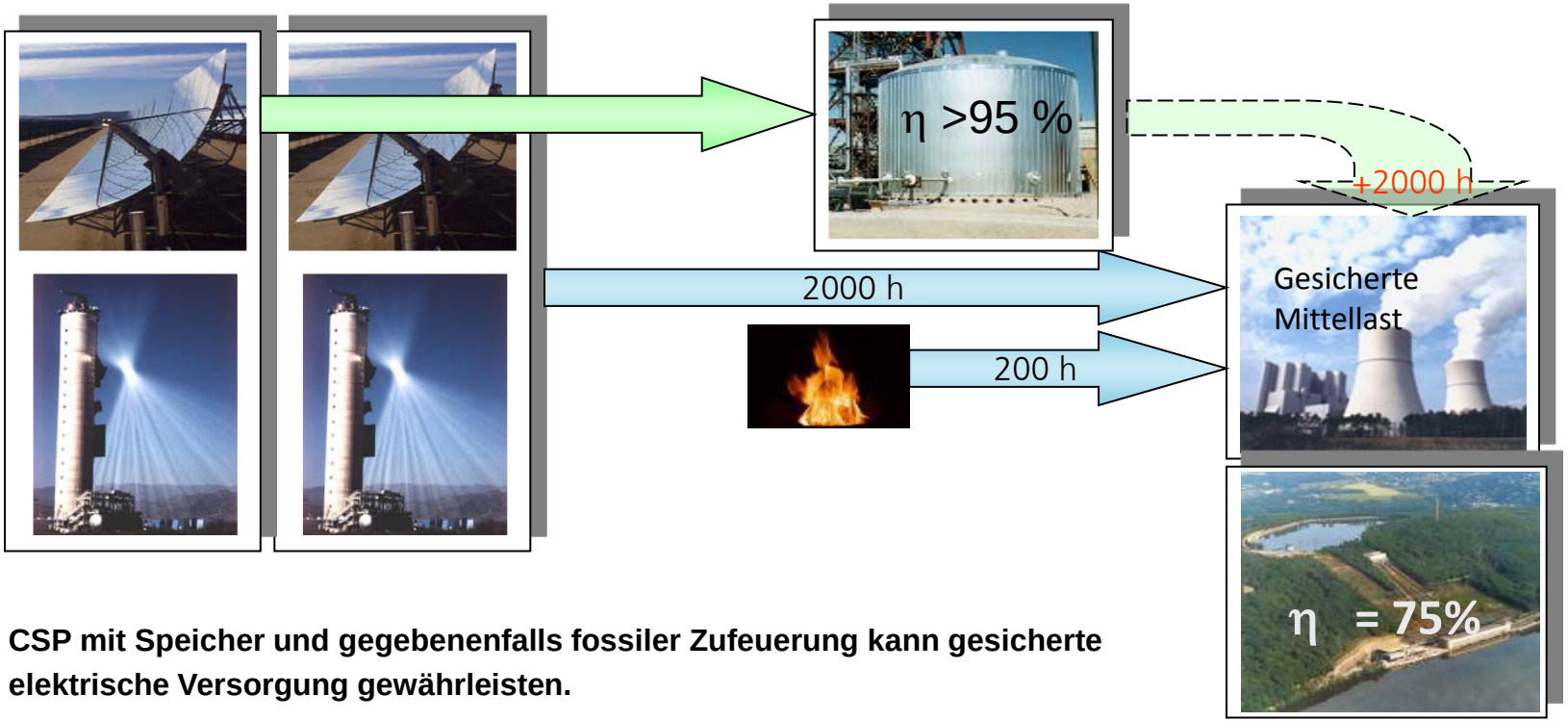
- In the north of Hohhot (Sanyuanjingxiang)
- Longitude: 112.11° East
- Latitude: 41.65° North
- Height: 1685m
- Solar Resource
  → 2227 kWh/a
- Distance to Beijing
  app. 420 km



Source: IA Tech GmbH, study 2013

Quelle: SWERA, 40 km Resolution by NREL

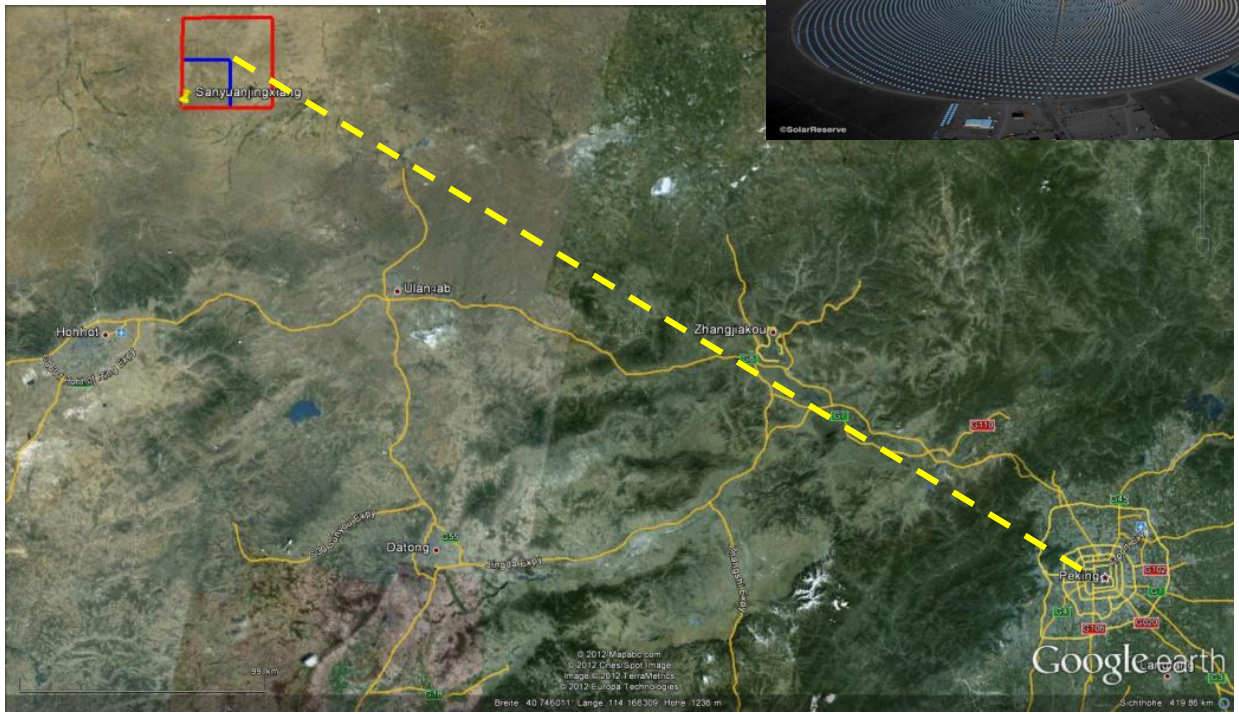
Thermischer Speicher gegenüber elektrischem Speicher



CSP mit Speicher und gegebenenfalls fossiler Zufeuerung kann gesicherte elektrische Versorgung gewährleisten.

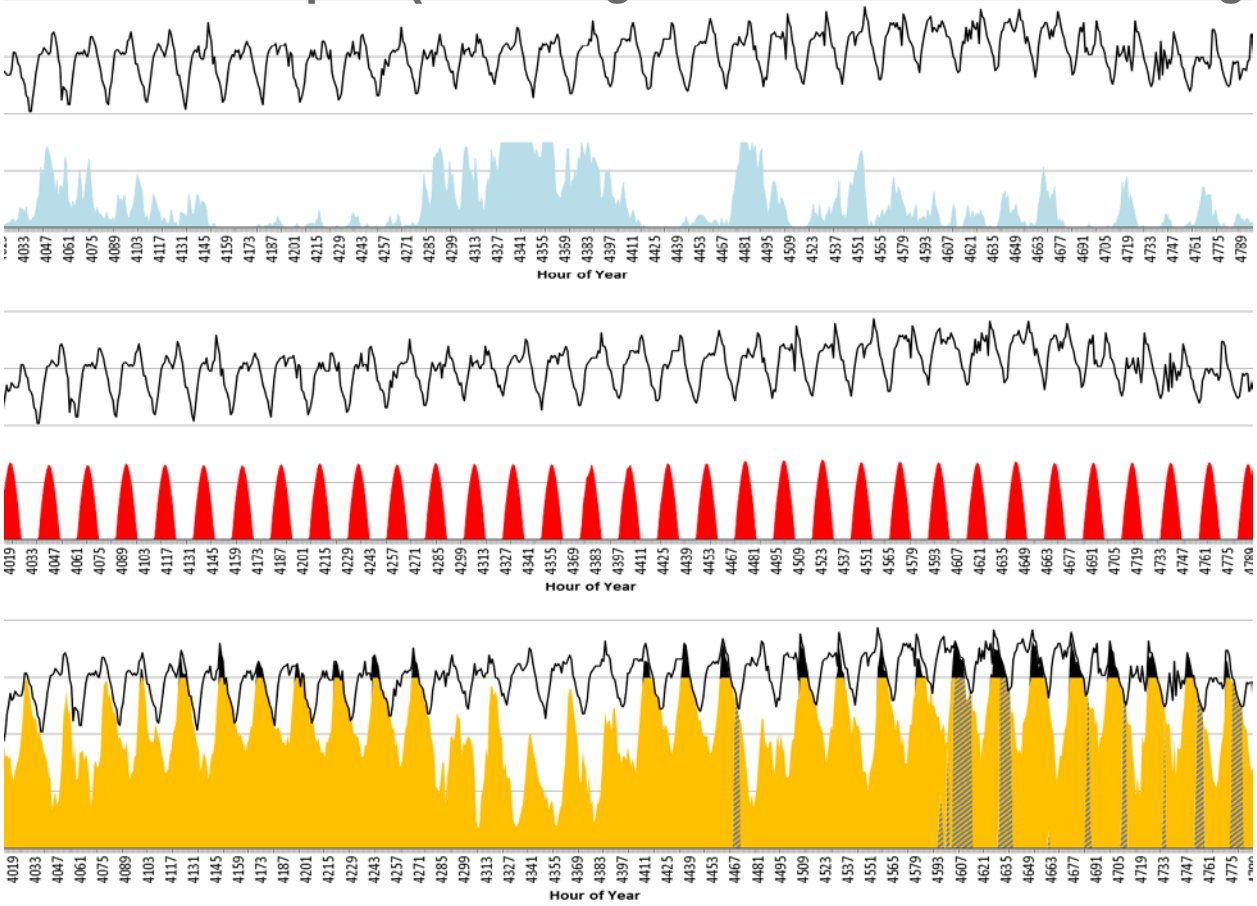
Solar Hotspot für Peking

- **Scenario I: 20% CSP**
  - **Salt 100**
    - → 33 plants
    - → 325 km²
    - → 18 x 18 km²
- **Scenario II: 70% CSP**
  - **Salt 100**
    - → 117 plants
    - → 1137 km²
    - → 34 x 34 km²
- **Übertragungsverluste**
  - **2,25%**



Quelle: LEONI / IA Tech Studie 2013

Regenerative Hotspot (100% regenerativ und 100% Versorgungssicherheit)



Wind

PV

Diesel

CSP

Quelle: Fallstudie TU Berlin

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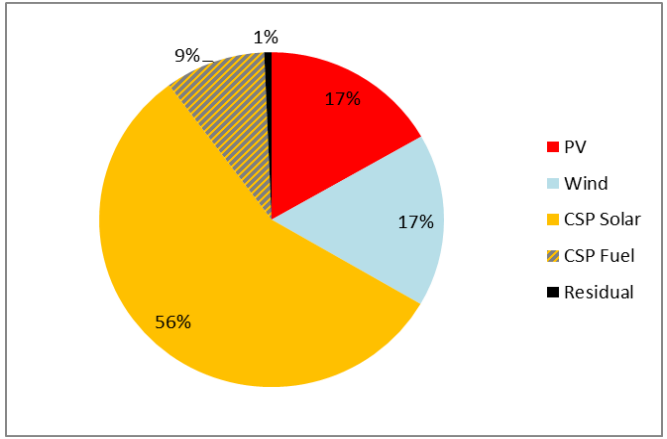
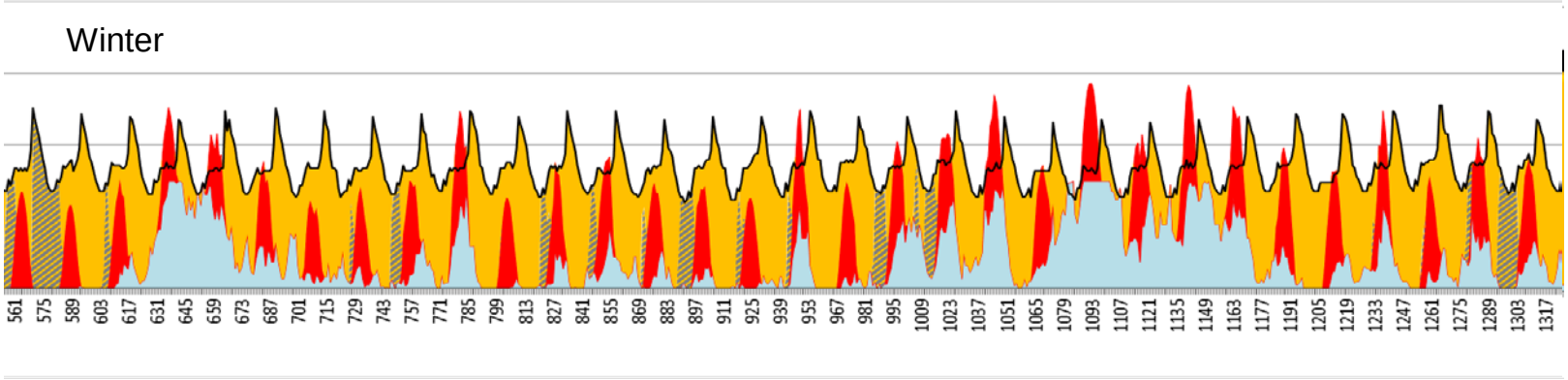
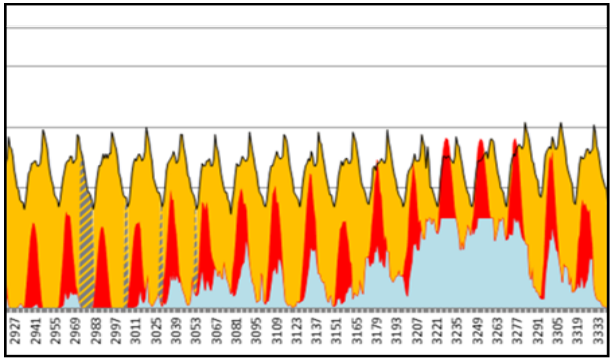




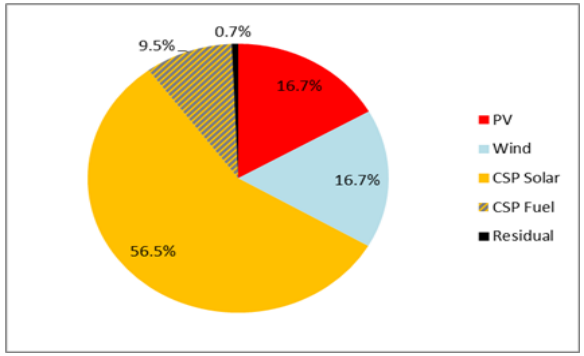
Quelle: Fallstudie TU Berlin

Regenerative Hotspot (100% regenerativ und 100% Versorgungssicherheit)

Ergebnis
für eine
Wüstenregion



Annual Share



Quelle: Fallstudie TU Berlin

Zusammenfassung

- Beobachtung einer massiven Agglomeration der Weltbevölkerung auf Ballungsräume und Entvölkerung der Landflächen => MegaCities > 100Mio. Einwohner
- Grund: Sozioökonomische-Besserstellung der Menschen in Ballungsräumen gegenüber der Landbevölkerung
- Voraussichtlich Konzentration von 75% der Weltbevölkerung auf weniger als 2,8% der Landfläche in 2050
- Regenerative dezentrale Selbstversorgung dieser Ballungsräume/MegaCities wahrscheinlich nicht möglich
- Versorgung der Ballungsräume aus „Solaren bzw. regenerativen Hotspots“ unter Sicherstellung einer 100% Versorgungssicherheit und Transport der Elektrizität mit HGÜ in die Ballungsräume

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